SVKM's
D. J. Sanghvi College of Engineering

Program: B.Tech in Mechanical Engineering **Academic Year: 2022** **Duration: 3 hours**
Date: 07.01.2023
Time: 10:30 am to 01:30 pm
Subject: Heat Transfer (Semester V) **Marks: 75**

Instructions: Candidates should read carefully the instructions printed on the question paper and on the cover page of the Answer Book, which is provided for their use.

(1) This question paper contains three pages.
(2) All Questions are Compulsory.
(3) All questions carry equal marks.
(4) Answer to each new question is to be started on a fresh page.
(5) Figures in the brackets on the right indicate full marks.
(6) Assume suitable data wherever required, but justify it.
(7) Draw the neat labelled diagrams, wherever necessary.

Question No.		**Max. Marks**
Q1 (a)	Explain the term critical insulation thickness. Derive an expression for the critical radius of insulation for a sphere.	[05]
Q1 (b)	i. A thermopane (thermally insulated glass) window that is 0.6 m long by 0.3 m wide comprises two 8 mm thick pieces of glass sandwiching an 8 mm thick stagnant air space. The thermal conductivity of glass is 1.4 W/m K and that of air is 0.025 W/m K. The window separates room air at 20°C from outside ambient air at –10°C. The convection coefficients associated with the inner (room side) and the outer (ambient) surfaces are 10 W/m^2K and 80 W/m^2K respectively. (a) Determine the heat loss through the window, and the two surface temperatures. (b) What would be the heat loss if the window had a single glass of 8 mm thickness instead of a thermopane? **OR** ii. A composite cylinder consists of 100 mm radius steel pipe of 25 mm thickness over which two layers of insulation 30 mm and 35 mm are laid. The conductivities are 25 W/mK, 0.25 W/mK and 0.65 W/mK. The inside is exposed to convection at 300°C with h = 65 W/m^2K. The outside is exposed to air at 30°C with h = 15 W/m^2K. Determine the heat loss per meter length. Also find the interface temperatures.	[10] [10]
Q2 (a)	For transient heat conduction, with negligible internal resistance with usual notations show that, $\frac{\theta}{\theta_i} = e^{(B_i \times F_o)}$.	[07]
Q2 (b)	i. A metal rod is attached horizontally to a large tank at a temperature of 200^0C. The rod has 1 cm diameter, 30 cm length and thermal conductivity of 65 W/mK. The rod dissipates heat by convection into the ambient air at 20^0C with heat transfer coefficient of 15 W/m^2K. What is the temperature of the rod at 10 cm and 20 cm from the tank? Assuming the rod as a long fin, Calculate the heat transfer rate, the fin efficiency and effectiveness.	[08]

	OR ii. The handle of a ladle used for pouring molten lead at 328°C is 30 cm long. Originally the handle was made of 1.3 cm by 2.0 cm mild steel bar stock. To reduce the grip temperature, it is proposed to form a hollow handle of 1.5 mm thick mild steel tubing to the same rectangular shape. The average heat-transfer coefficient over the handle surface is 17 W/m^2K, when the ambient air temperature is 28°C. The thermal conductivity of mild steel is 43 W/m^2K. Determine the reduction in the temperature of the grip, stating the assumptions made.	[08]
Q3 (a)	Using Buckingham's π method, derive an expression for heat transfer coefficient in free convection in terms of Nusselt number, Grashof number and Prandtl number.	[07]
Q3 (b)	i. A refrigerated truck is moving at a speed of 85 km/h where ambient temperature is 50°C. The body of the truck is of rectangular shape of size 10 m (Length), 4 m(Width) and 3 m(Height). Assume the boundary layer is turbulent and the wall surface temperature is at 10°C. Neglect heat transfer from vertical front and backside of truck and flow of air is parallel to 10 m long side. Calculate heat loss from the four surfaces. For turbulent flow over flat surfaces: $Nu = 0.036\ Re^{0.8} \times Pr^{0.33}$ Average properties of air at 30°C: $\rho = 1.165\ kg/m^3$, Cp = 1.005 kJ/kgK, $\nu = 16 \times 10^{-6}\ m^2/s$, Pr = 0.701 **OR** ii. A hot, square plate, 50 cm × 50 cm, at 100°C is exposed to atmospheric air at 20°C. Find the heat loss from both the surfaces of the plate: (i) if the plate is kept vertical (ii) if the plate is kept horizontal. Properties of air at mean temperature of 60°C are given below: $\rho = 1.06\ kg/m^3$, k = 0.028 W/mK, $\nu = 18.97 \times 10^{-6}\ m^2/s$, Cp = 1.008 kJ/kgK. Following empirical relations can be used: Case (i): $Nu = 0.13 \times (Gr\ Pr)^{1/3}$ Case (ii): $Nu = 0.71 \times (Gr\ Pr)^{1/4}$ for the upper surface, and $Nu = 0.35 \times (Gr\ Pr)^{1/4}$ for the lower surface.	[08] [08]
Q4 (a)	A spherical liquid oxygen tank, 0.3 m in diameter is enclosed concentrically in a spherical container of 0.4 m diameter and the space in between is evacuated. The tank surface is at – 183°C and has an emissivity of 0.2. The container surface is at 25°C and has an emissivity of 0.25. Determine the net radiant heat transfer rate.	[05]
Q4 (b)	Solve any **two** of the following i. State and explain Kirchhoff's law of radiation. ii. Write a short note on properties of view factor. iii. State Wein's law of displacement and prove that monochromatic emissive power of a black body is maximum when λmT = constant.	[05] [05] [05]
Q5 (a)	A chemical (Cp = 3.3 kJ/kgK) following at the rate of 20000 kg/hr enters a parallel flow heat exchanger at 120°C. The flow rate of cooling water (Cp = 4.186 kJ/kg K) is 50000 kg/h with an inlet temperature of 20°C. The heat-transfer surface area is 10 m^2 and the overall heat transfer coefficient is 1050 W/m^2K. Calculate the (a) effectiveness of the heat exchanger, and (b) outlet temperatures of water and chemical.	[07]

Q5 (b)	i.	Derive an expression for the LMTD of a counter flow type heat exchanger. Also list the assumptions made in the analysis. **OR**	[08]
	ii.	Starting from basics, derive an equation for the effectiveness of a parallel-flow heat exchanger in terms of NTU and capacity ratio.	[08]